KLM Technology Group P. O. Box 281 Pejabat Pos Bandar Johor Bahru, 80000 Johor Bahru, Johor, West Malaysia	**Kolmetz Handbook Of Process Equipment Design** **FLARE KNOCK OUT DRUM SELECTION, SIZING AND TROUBLESHOOTING** **(ENGINEERING DESIGN GUIDELINES)**	Co Author Rev 01 Faulina Popy Puspita Author / Editor Karl Kolmetz

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INTRODUCTION

SCOPE

The primary function of a flare is to use combustion to convert flammable, toxic, or corrosive vapors to less objectionable compounds. Selection of the type of flare and the special design features required are influenced by several factors such as, including the availability of space; the characteristics of the flare gas, namely, composition, quantity and pressure level; economics, including both the initial investment and operating costs; and public relations.

Public relations can be a factor if the flare can be seen or heard from residential areas or navigable waterways. Other topographic considerations include elevations of land and neighboring land, elevations of equipment (especially where personnel might need to be present), and proximity to utility and electrical systems (e.g. electric lines or control wire runs). The designer needs to know these and other factors in the determination of noise, thermal radiation, liquid carryover and vapor dispersion. For example, a flare near a hill or in a valley can be influenced by wind direction and downward turbulence.

The flare provides a means of safe disposal of the vapor streams from its facilities,with burning them under controlled conditions such that the adjacent equipment or personnel are not exposed to hazards, and at the same time obeying the environmental regulation of pollution control and public relations requirements.

The Knock out drum is a vessel in the flare header designed to remove & accumulate condensed and entrained liquids from the relief gases. Knockout drums are one of the main components in pressure-relief systems in industries. Pressure-relief systems in refineries are used to control vapors and liquids that are released by pressure relieving devices and blowdowns.

GENERAL DESIGN CONSIDERATION

A. What Is Flaring ?

Many industries generate significant amounts of waste streams, such as hydrocarbon vapor, which must be disposed of, a continuos or intermittent basis. Some of the examples can be like off-spec product or the bypass streams generated during start - up operations. Direct discharge of waste gas streams and vapors into the atmosphere is unacceptable due to safety and enviromental control considerations.

Gas flaring is a standard operation aimed at converting flammable, toxic, and corrosive vapor to less objectionable compunds by means of combustion. Flaring is a critical operation in many plants where design must be based on strict safety principles.

B. Why is Flaring required ?

In general proper planning and layout of process plants require that special consideration be given to the design of various safety facilities to prevent catastrophic equipment failure. These facilities are designed to prevent overpressure and to provide for safe disposal of discharged vapors and liquid. Portions of these facilities are also used as an operational tool for safe disposal of hydrocarbons – particulary during start – up and shutdwon phases.

Standard pressure relieving devices most often used are safety and relief valves, ruptur disks, pressure control valves and blowdowon valves. Direct discharge of waste or excess vapor to atmosphere is unacceptable either.

1. Because of restrictions imposed by local ordinaces or plant practices.
2. Concentrations of the contaminants at ground or adjacent platform levels may exceed permissible explosion or toxicological thershold limits.
3. Meteorogical considerations such as severe temperature inversions of long duration may occur, creating hazardous conditions.

Types of Flare

There are basically two types of flare system namely Elevated Flares and Ground Flares.Selection of the type of flare is influenced by several factors, such as availability of space; the characteristics of the flare gas (composition, quantity and pressure); economics; investment and operating costs; public relations and regulation.

I) Elevated Flare

Elevated flare (refer Figure 1) is the most commonly used type in refineries and chemical plants. They have larger capacities than ground flares. The waste gas stream is fed through a stack from 32 ft to over 320 ft tall and is combusted at the tip of the stack.

The elevated flare, can be steam assisted, air assisted or non-assisted. The elevated flare can utilize steam injection / air injection to made smokeless burning and with low luminosity up to about 20%+ of maximum flaring load. The disadvantage of steam injection / air injection is it introduces a source of noise and may cause noise pollution.

If adequately elevated, this type of flare has the best dispersion characteristics for malodorous and toxic combustion products. Capital costs are relatively high, and an appreciable plant area may be rendered unavailable for plant equipment, because of radiant heat considerations.

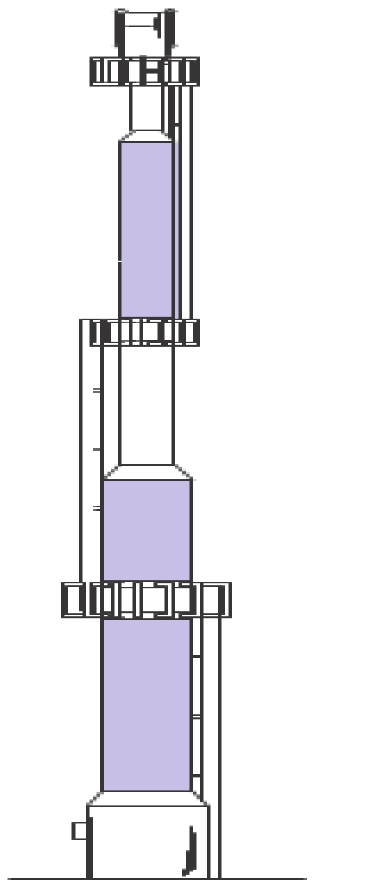

Figure : 1 Elevated Flare

II) Ground Flare

A ground flare is where the combustion takes place at ground level. It varies in complexity, and may consist either of conventional flare burners discharging horizontally with no enclosure or of multiple burners in refractory-lined steel enclosures. The type, which has been used almost exclusively, is the multijet flare (enclosed type).

The difference with an elevated flare, the ground flare can achieve smokeless operation as well, but basically there is no noise or luminosity problem, provided the design gas rate to the flare is not exceeded. However, it have poor dispersion of combustion product because its stack is near to ground, this may result in severe air pollution or hazard if the combustion products are toxic or in the event of flame-out. Capital, operating and maintenance requirements cost are higher.

Because of poor dispersion, multijet flare is suitable for "clean burning" gases when noise and visual pollution factors are critical. Generally, it is not practical to install multijet flares large enough to burn the maximum release load, because the usual arrangement of multi jet flare system is a combination with an elevated over-capacity flare.

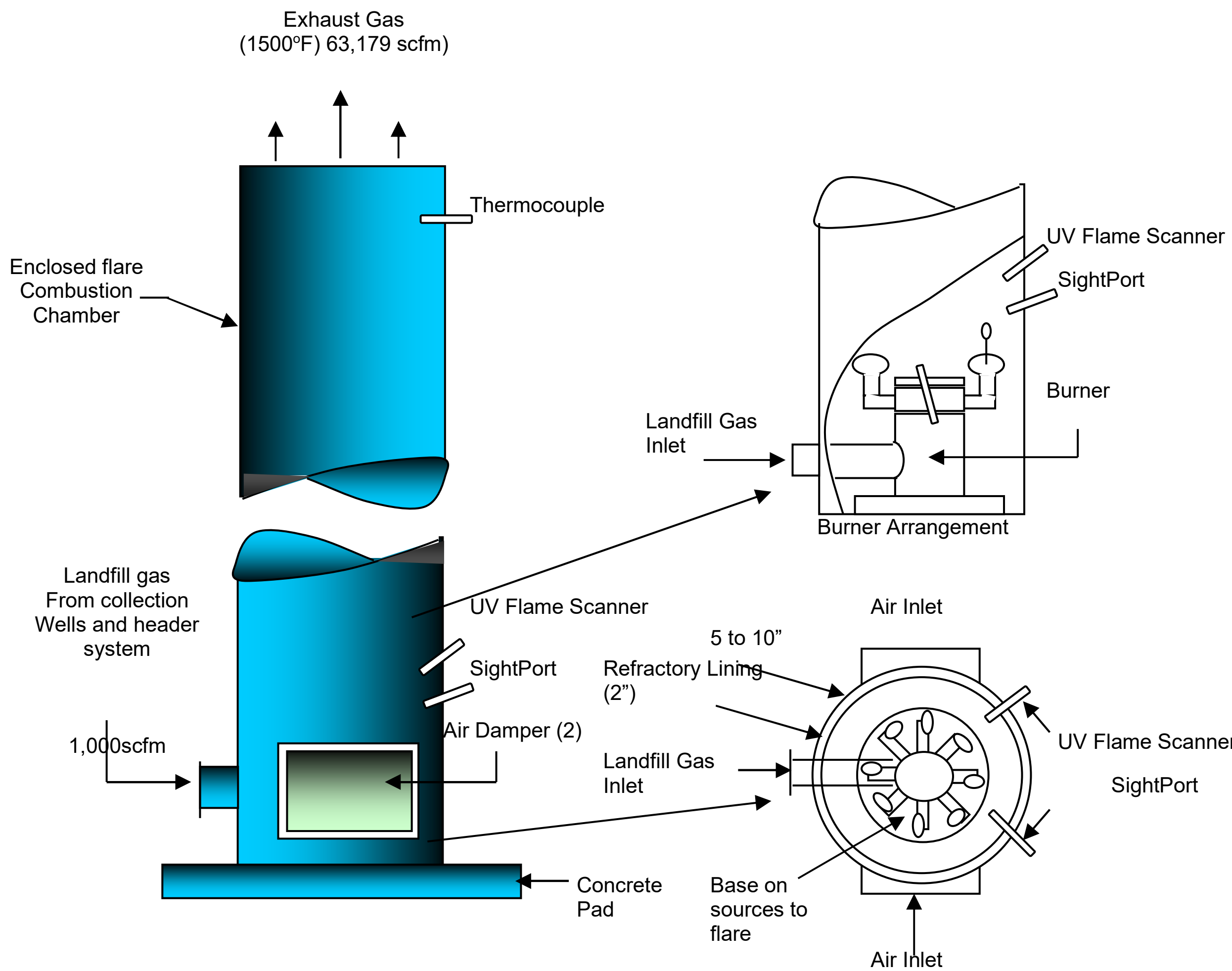

Figure 2 : Typical Ground Flare

Flare System

Typical flare system are :

i) Gas collection header and piping for collecting gases from processing units,
ii) A knockout drum to remove and store condensable and entrained liquids,
iii) A proprietary seal, water seal, or purge gas supply to prevent flash-back
iv) A single or multiple burner unit and a flare stack,
v) Gas pilots and an igniter to ignite the mixture of waste gas and air and
vi) A provision for external momentum force (steam injection or forced air) for smokeless flaring.

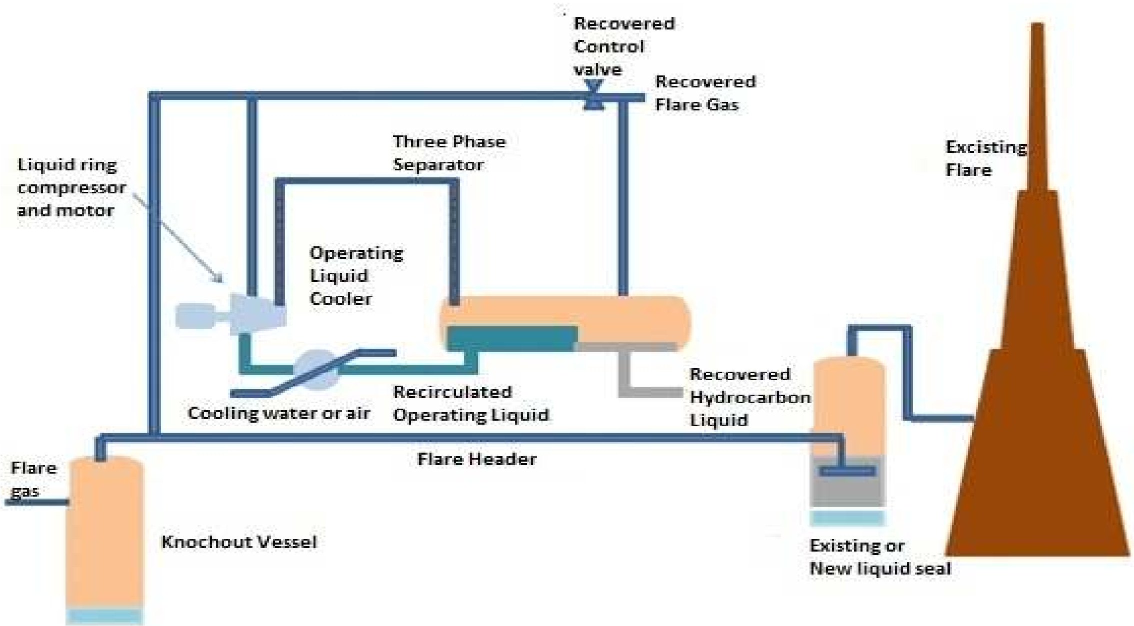

Figure 3 : Representation of a flare gas recovery unit integrated with an existing flare system.

Design Factors

Is very important for the flare designer to understand several factors which can affect his flaring system design, the major factors influencing flare system design are:

I) Flow Rate

How flow rate will affect the design of flare system? Normally the designer of the flare system will follow exactly the flow data provided, therefore overstated of the flows will lead to oversized of flare equipment which lead to more expensive capital and operating costs and can lead to short service life as well. Understated the flow can result in a design of an unsafe system.

Flow rate obviously affects the mechanical size of flare equipment, increased flow will results increase of thermal radiation from an elevated flare flame, which have direct impact on the height and location of a flare stack.

II) Gas composition

The combustion gas products are depend on the feed gas composition, by studying the feed gas composition the potential combustion product can be determined and burning characteristic can be identified. It enables the design company to shown the weight ratio of hydrogen to carbon in gas which indicates the smoking tendency of the gas. Some gas, such as hydrogen sulfide will need special design for metallurgies, therefore detail of the feed gas compositions to design the flare system is very important and should be determined accurately.

III) Gas Temperature

Gas temperature has direct impact on thermal expansion, gas volume and metallurgical requirements for pipe & vessels. Beside this the more important impact of gas temperature to flare design is the potential of substance / components of the gas to condense, because condensation or two-phase flow will cause a greater smoking tendency and/or the possibility of a burning liquid rain. This can be solved by adding a liquid removal equipment such as a knockout drum.

IV) Gas Pressure Available

The gas pressure available for the flare is determined by hydraulic analysis of the complete pressure relief system from the pressure relieving devices to the flare burner. This parameter is a factor for smokeless burning design of flare. Some flare design companies have proved that smokeless burning can be enhancedby converting as much of the gas pressure available as possible into gas momentum. With the higher pressure drop across the flare burner it can reduce the gas volume, which can lead to a smaller flare header size & reduced cost and finally allows a reduction in purge gas requirements.

V) Utility Costs and Availability

To achieve smokeless operation, it is necessary to add an assist medium to increase the overall momentum to the smokeless burning level. The common medium is steam which is injected into nozzles of the flare system. In order to achieve this objective, local energy costs, availability and reliability must be taken into account in selecting the smoke-suppression medium.

Other utilities are needed to be in place are purge gas and pilots. The quantity required is depending on the size of the flare system. The purge gas requirement can be influenced by the composition of the purge gas and/or the composition of the waste gas. Pilot gas consumption will also be influenced by the combustion characteristics of the waste gases.

VI) Environmental Requirements

The primary environmental requirement is the need for smokeless burning to protect the environment from pollution, it may be necessary to inject an assist medium such as steam in order to achieve smokeless burning. Unfortunately the injection of the steam and the turbulence created by the mixing of steam to solve the smoke burning problem causes the emission of sound. The sound level at inside and outside the plant boundary is often limited by regulation.

VII) Safety Requirements

The main safety concern for the flaring system is thermal radiation issues. The allowable radiation from the flare flame to a given point is frequently specified based on the owner's safety practices by following the safety regulation. Special consideration should be given to radiation limits for flares located close to the plant boundary.

VIII) Social Requirements

Although the plant operation has complied with the environmental regulation, sometime the outcome resulting flare system may not meet the expectations of the plant's neighbors. Example: A smokeless flame may meet the regulatory requirements, but the neighbors may complaint due to light and noise from flare system.

Knockout Drum

The Knock out drum is a vessel in the flare header designed to remove & accumulate condensed and entrained liquids from the relief gases. Both the horizontal & vertical design is a common consideration for the Knock out drum, which is determined based on the operating parameters as well as other plant conditions. If a large liquid storage capacity is desired and the vapour flow is high, a horizontal drum is often more economical. Also, the pressure drop across horizontal drums is generally the lowest of all the designs. Vertical knockout drums are typically used if the liquid load is low or limited plot space is available. They are well suited for incorporating into the base of the flare stack.

Knockout drums are a main component in pressure-relief systems in industries. Pressure-relief systems in refineries are used to control vapors and liquids that are released by pressure- relieving devices and blowdowns. A typical closed pressure-release and flare system device includes the following:

(a) relief valves and lines from process units for collection of discharges,

(b) knockout drums that are used to separate vapors or gas and liquids, including seals and/or purge gas for flashback protection,

(c) a flare and igniter system that combusts vapors when discharging directly to the atmosphere is not permitted.

Knockout drums and flare systems need to be designed appropriately, because they can cause equipment failures which can result in economic losses for business, environmental contamination, and health and safety risks in case of excessive pressure.

Therefore, the proper relief effluent handling equipment design is required. In this paper, the optimal design of two-phase horizontal-oriented knockout drums for oil industry applications is addressed.

Horizontal-oriented knockout drums are often more economical when large liquid storage is desired and the vapor flow is high. In offshore applications, refineries, and petrochemical industries, knockout drums are designed to effectively remove hydrocarbon liquids from the main flare relief gas to prevent the possibility of liquid carryover and “flaming rain” from the flare tip. Knockout drums are classified as “two phase” if they separate gas from the total liquid stream and “three phase” if they also separate the liquid stream into its crude oil and water compo- nents.

The design of knockout drums typically is based on manual trial-and-error procedures with widespread table lookups that require the expert application of many rules-of-thumb. Such as knockout drum design methods provide limited tools for the designer because of the nature of multivariable manual trial- and-error procedures. Approaches based on simple force balance and correlations for drag force on a spherical droplet have been also reported.

Anaya et al., have addressed the knockout drum design via a systematic design procedure for a two-phase knockout drum. The authors developed a heuristic algorithm to search out model convergence on the basis of the economical ratio of minimum length as a function of diameter.

A parametric optimization approach to search minimizing the separator vessel manufacturing cost is proposed. The main concept behind the proposed procedure is based on the successive solution of a nonlinear programming (NLP) model. It is shown that the proposed design procedure allows the robust solution for the optimal design of knockout drums under a variety of different scenarios. The optimization model and its heuristic solution algorithm are applied to determine the optimal horizontal knockout drum design for a nominal set of design parameters.

The problem is constrained by a set of fluid dynamic and mechanical relationships formulated from the gravity-settling theory. The application of the parametric optimization procedure is illustrated through the solution of a case study. Also performed is an in-depth analysis aimed to characterize liquid–gas separation in horizontal knockout drum. For the sake of clarity in presentation, we briefly discuss fundamentals in separator design. the optimization model, model constraints, and objective function are presented. Followed by the application of the proposed parametric approach for the optimal design.

Although horizontal and vertical knockout drums are available in many configurations, the differences are mainly in how the path of the vapour is directed. The various configurations include the following:

a) Horizontal drum with the vapour entering one end of the vessel and exiting at the top of the opposite end (no internal baffling);

b) Vertical drum with the vapour inlet nozzle entering the vessel radially and the outlet nozzle at the top of the vessel's vertical axis. The inlet stream should be baffled to direct the flow downward;

c) Vertical vessel with a tangential nozzle. Vertical centrifugal separators differ from vertical settling drums in that the flow enters tangentially and spins around a centre tube, which extends below the liquid inlet nozzle. The gas and liquid flow radially downward through the annulus causing liquid droplets to coalesce along the walls and collect in the bottom of the drum. The vapour changes direction once below the centre tube and flows upward to the outlet nozzle. To avoid liquid re-entrainment, vapour velocity has to be kept low in the turnaround section of the drum. An additional measure to prevent liquid re-entrainment is a baffle plate below the turnaround section of the drum. The maximum liquid level is the same as vertical settling drums;

d) Horizontal drum with the vapour entering at each end on the horizontal axis and a centre outlet;

e) Horizontal drum with the vapour entering in the centre and exiting at each end on the horizontal axis

f) Combination of a vertical drum in the base of the flare stack and a horizontal drum upstream to remove the bulk of the liquid entrained in the vapour. This combination permits the use of larger values for the numerical constant in the velocity equation.

DEFINITION

Back Pressure- Back pressure is the sum of the superimposed and build-up back pressures. The pressure that exists at the outlet of a pressure relief device is as a result of the pressure in the discharge system.

Gas Blower - Device for blowing air to flare system.

Blowdown - The difference between the set pressure and the closing pressure of a pressure relief valve, expressed as a % of the set pressure of in pressure units.

Closed Disposal System- Disposal system which is capable of containing pressure that is different from atmospheric pressure.

Flare System – A system that safely disposing of waste gases through the use of combustion.

Flare Stack- Is an elevated vertical stack found on oilwells or oil rigs, and in refineries, chemical plants and landfills used for burning off unusable waste gas or flammable gas and liquids released by pressure relief valves during unplanned over-pressuring of plant equipment.

Flame Arrestors- A crimped ribbon aluminum or stainless steel flame cell to protect against rapid burn backs in low-pressure situations. These passive safety device guaranteed to prevent flame fronts from propagating back through lines, destroying facilities, and causing injuries.

Flare Tips- Structure at top of the flare play the role to keep an optimum burn and control over all flow rates, which results in a cleanercombustion. The design of the tip makes sure that the tip does not come into contacting with the flame making the tips reliable and long lasting.

Horizontal Drum - drum clamp has been designed to lift and transport drums in the horizontal position.

Ignitions system – Is a system use to ignite the flare of flare systems. Normally this system designed to ignite the flare quickly the first time, maintain combustion and re-ignite rapidly to prevent industrial hazards and personal injury while protecting the environment.

Knockout Drum – Is a drum installed near the flare base, and serves to recover liquid hydrocarbons, prevent liquid slugs, and remove large liquid particles from the gas streams released from relief system.

Meteorogical - Meteorological events include things like fog, rain, tornadoes, and hurricanes. They are all caused by meteorological changes and shifts: in the temperature, air pressure, and amount of water vapor in the atmosphere.

Open Disposal System- A disposal system that discharges directly from relief system to atmosphere without other devices.

Overpressure- Pressure value increase more that the set point pressure of the relieving device, expressed in percent.

Pressure Relieving System- An arrangement of a pressure-relieving device, piping and a means of disposal intended for the safe relief, conveyance, and disposal of fluids in a vapour, liquid, or gaseous phase. It can be consist of only one pressure relief valve or rupture disk, either with or without discharge pipe, on a single vessel or line.

Relief Valve – A spring-loaded pressure relief valve is actuated by the static pressure upstream of the valve. The valve opens normally in proportion to the pressure increase over the opening pressure. A relief valve is used primarily with incompressible fluids.

Rupture Disk Device- A non reclosing differential pressure relief device actuated by inlet static pressure and designed to function by bursting the pressure containing rupture disk. A rupture disk device includes a rupture disk and a rupture disk holder.

Support Structure – Structure which designed to withstand local wind condition for flares. Three types available self-supported, Guy-wire supported and Derrick supported.

Vertical Drum - drum clamp has been designed to lift and transport drums in the vertical position.

Windbreaker - A windbreaker is structure uses to prevent the wind from extinguishing the flames which located at flare tip. It serves also to hide the flames.

NOMENCLATURE

A_t	Flare tip area, ft^2
C	Drag coefficient (Dimensionless)
d_j	Pipe/Tip inside diameter, ft
D	Particle diameter, in
g	Acceleration due to gravity, 32.2 ft/s^2
H	Heat of combustion gases, Btu/Ib
h	Distance, in feet
k	Ratio of specific heats (C_p/C_v)
L_f	Flame length, ft
Mach	Mach number at pipe outlet
M_j	Gas molecular weight
m	Mass flow rate, Ib/s
P	Maximum header exit pressure, in Ib/in^2g
P_j	Pipe outlet pressure, in Ib/in^2 (absolute)
Q_f	Heat release, Btu/hr
q_f	Heat intensity ($Btu/hr/ft^2$)
R	Gas constant, 10.7 (British unit)
R_f	Distance from the midpoint flame (ft)
T_j	Absolute temperature, in ^oR
U_d	Maximum allowable vapor velocity for vertical vessel, ft/s
U_∞	Design wind velocity
V	Volumetric flowrate, ft^3/s
W	Gas flow rate, in Ib/hr
W_{stm}	Mass flow rate of steam, Ib/hr
Z	Compressibility factor, dimensionless

Greek letters

ε	Emissivity, (dimensionless)
ρ	Sealing liquid density, in lb/ft^3
ρ_L	Density of liquid, lb/ft^3
ρ_V	Density of vapor, lb/ft^3